

Research Paper

Context and intentions: practical associations for fecal sludge management in rural low-income Cambodia

James Harper, Angela Bielefeldt, Amy Javernick-Will, Toeur Veasna and Chris Nicoletti

ABSTRACT

Finite storage capacities of household pit latrines make safely managing fecal sludge a recurring challenge for 2.7 billion people globally. Frequently without guidance from standards or regulation, rural latrine owners choose how to manage their own fecal sludge. However, their intentions – what behavioral science says are the best predictors of future behaviors – when pits fill are poorly understood, inhibiting the development of safe fecal sludge management (FSM) solutions and deteriorating public and environmental health. Using survey data commonly measured by development practitioners, we analyze response frequencies and their associations with contextual factors, such as location, month that the survey was administered, and poverty level. We also use binomial logistic regression to determine if contextual factors can be used to predict the intentions of rural Cambodian latrine owners when pits fill. We found that four in ten rural latrine owners intend to manage their fecal sludge unsafely (41%), and one in six did not have a plan (16%). Desirable FSM intentions increased markedly after rice harvest and varied markedly across provinces. Many predictors of desirable FSM intentions, such as location and satisfaction with the household's latrine, were also identified. Associations between FSM intentions and contextual factors can be used to help predict FSM behaviors and improve FSM service delivery, behavior change campaigns, and product design. However, future work should seek to characterize the complete decision-making processes of rural latrine owners when pits fill.

Key words | Cambodia, context, fecal sludge management, intention, rural, sanitation

BACKGROUND

Pit latrines are used daily by approximately 2.7 billion people in rural low-income communities globally and are being installed in record numbers throughout Southeast Asia (Strande 2014). Because latrines only contain and store human waste, use must cease when a pit fills until the pit can be emptied or an additional pit installed. To

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protect public health via safely managed sanitation, pit emptying or installation must be performed by trained individuals, typically professional services, who use specific methods and equipment that prevent human contact with pathogenic fecal sludge. Unfortunately, such services are frequently unavailable or expensive to rural latrine-owning households ('latrine owners' henceforth) (Hussain *et al.* 2017). Therefore, rural latrine owners typically empty their own pits using unsafe behaviors that endanger the pit emptier, community members, and/or the environment via

exposure to fecal sludge (Still & Foxon 2012). Unsafe methods include a latrine owner emptying their own pit (self-empty); releasing fecal sludge into floodwaters by opening a pit's lid during a flood (flooding out); or stopping latrine use. It is important to note that while self-empty can be performed safely if personal protective equipment is worn, and proper techniques are used (Strande & Brdjanovic 2014), the literature describing rural fecal sludge management (FSM) in Cambodia shows that these safe procedures are rarely followed during self-empty (Kong & Bartell 2018; SNV 2019); thus, this study considers self-empty to be unsafe. Safe FSM, which includes the collection, transport, treatment, and disposal of fecal sludge, must be achieved to mitigate serious health and environmental consequences.

In rural communities, latrine owners typically choose how to manage their own fecal sludge. Research, however, has largely focused on technologies and economics (Strande & Brdjanovic 2014) while largely ignoring household-level decision-making (Jenkins Cumming & Cairncross 2015). The decision-making processes of latrine owners strongly affect the adoption, use, and maintenance of sanitation systems (Jenkins & Scott 2007; Sample Evans Camargo-Valero Wright & Leton 2016; Coffey Spears & Vyas 2017). Within Cambodia, a country with a large rural population that relies on on-site sanitation systems, a study in three provinces ($n = 39$) and a study in two provinces ($n = 633$) provide some information about household-level decision-making when pits fill (Kong & Bartell 2018; PSI 2018; SNV 2019). However, due to their limited geographic distributions, these studies could not draw conclusions about how intentions, the best predictor of future behaviors (Fishbein & Ajzen 2011), when pits fill – hereafter called ‘FSM intentions’ – vary by region, season, and other contextual factors across Cambodia, the focus of this study.

FSM intentions describe how willing a person is to perform certain behaviors related to FSM. Various models of decision-making describe how context affects the formation of intentions (Darnton 2008). Contextual factors can be categorized as personal (e.g., education, emotions, age, gender, income, religion), societal (e.g., social norms, culture, economy, politics), or physical (e.g., geography, season, weather, environment) (Fishbein & Ajzen 2011). The contextual factors that are relevant to one behavior may be irrelevant to another. Past studies of rural sanitation identified factors

relevant to latrine adoption and maintenance behaviors, including availability of funds, physical space, service provision, the defecation practices of neighbors (a social norm), and a latrine owner being satisfied with their latrine (an attitude) (Jenkins & Scott 2007; Coffey *et al.* 2017). While all components of the decision-making process are of interest, we analyze if contextual factors commonly measured by development practitioners and other agencies can be used to predict the FSM intentions of rural Cambodian latrine owners across seven provinces.

METHODS

Research context and data collection

Cambodia is a lower-middle-income country of approximately 16 million people with approximately 80% living in rural areas (Asian Development Bank 2014). Much of Cambodia's economy (60%) is based on rice cultivation along its major waterways (Figure A1 in Appendix A) (Food and Agriculture Organization of the United Nations 2014).

Since 2010, the international development organization iDE has studied how latrine owners in rural Cambodia perceive and interact with sanitation systems, which are primarily pour-flush single-pit latrines (iDE Cambodia 2017). To improve sanitation marketing, iDE Cambodia developed a survey in 2014 to describe the experiences, intentions, and behaviors of rural latrine owners regarding the construction, use, maintenance, and improvement of their household's latrine. Sixty-seven survey questions asked about latrine owners' current and past defecation behaviors; intentions when pits fill; household demographics and locations; latrine construction details and costs; satisfaction with their latrine and its installer; and various personal, societal, and physical contextual factors. The questionnaire was developed and administered prior to iDE partnering with the first three authors to study FSM intentions.

The survey was administered to 3715 rural latrine owners who had purchased their latrine within 6 to 12 months before the survey. This sampling frame was selected to understand how latrine owners that do not currently have full pits are planning for their pit filling in the future, which usually occurs after 3–6 years (iDE Cambodia 2017). Each latrine

owner was randomly selected from rural households that had purchased their latrine from an iDE-affiliated latrine installer in seven Cambodian provinces (Oddar Meanchey, Banteay Meanchey, Siem Reap, Kampong Thom, Kandal, Prey Veng, and Svay Rieng; Figure A1). Local iDE research assistants that speak native Khmer and live locally were trained both in classroom and field exercises to ensure accurate and repeatable survey administration. Surveys were administered in-person with rural latrine owners, and the data collected was reviewed by iDE's Monitoring and Evaluation managers and the authors for accuracy and completeness. Responses were recorded by research assistants digitally in TaroWorks (taroworks.org). Poverty level was self-reported by respondents based on their status in the Cambodian national government's Identification of Poor Households (IDPoor) Programme (Ministry of Planning Government of Cambodia 2012). The number of surveys administered per year increased from 2015 to 2017 due to increasing latrine sales and iDE's surveying capacity.

The demographic frequencies of latrine owners surveyed in this study matched the averages of the provinces they lived in, allowing generalizability of this study's results to the rural populations of each province surveyed.

Data analysis

We categorized responses to the question 'When your pit is getting full, what do you intend to do?' as desirable or undesirable FSM intentions. Desirable FSM intentions are held by latrine owners that intend to manage their FS safely by either paying for professional emptying or installing a new pit. Within this study, desirable FSM intentions provide an *opportunity* for safe FSM; for example, paying for professional emptying provides the opportunity for safe FSM because regulating FSM service operators is at least possible, while regulating how every household empties their own latrine is effectively impossible. All other intentions, including self-emptying, stopping latrine use, and being undecided, were defined in this study to be undesirable because they are unlikely to provide an opportunity for safe FSM. We analyzed the frequency of specific FSM intentions, their desirability, and associations with personal, societal and physical contextual factors.

Personal contextual factors included poverty level (type 1, type 2 or not) (Ministry of Planning Government of Cambodia

2012); latrine usage (frequently, sometimes, rarely, unknown); defecation behaviors before constructing the household's latrine (practiced open defecation, used neighbor's latrine); satisfaction with the latrine and its installer (very unsatisfied through very satisfied in five steps, unknown); whether a household had recommended a latrine or its installer to a friend; and whether a household intended to improve their latrine within three years (improve shelter, flush-water reservoir, shower, new pit, sink, other). We investigated one societal contextual factor: how many members of their community households believed to practice open defecation (most, some, few). Physical contextual factors included challenges with the latrine (clogging, smells, flooding, insufficient flush water, full or overflowing); the province where the household was located; whether the household was located near a river or pond; the year and month the data was gathered; and the monthly average rainfall for the household's province. See Table B1 (Appendix B) for more details.

Following new recommendations from the American Statistics Association (Wasserstein Schirm & Lazar 2019), associations that are of low uncertainty and practical benefit to rural FSM are reported and discussed. We define 'of low uncertainty' in this study as 'having a statistical significance (p) that is less than 0.1' and 'of practical benefit' as 'capable of helping predict rural FSM behaviors or improve rural FSM services, behavior change campaigns, policies or product design'. In this study, we report associations between FSM-intention desirability and factors that either (1) have been shown to associate with other aspects of rural sanitation systems (e.g., latrine access or use) in the literature; or (2) provide practical benefit to rural FSM development. Statistical significances (p -values) were calculated using the chi-squared test and are reported for all tests, and statistical importances are reported as either Cramer's v or a point-biserial correlation r_{pb} .

A binomial logistic regression model was created to predict the desirability of FSM intentions (dependent variable). Contextual factors measured in the survey were used as independent variables in the model. The model was developed iteratively, starting with all contextual factors measured in the survey as inputs. After the model was run once, we removed the factor that contributed the smallest reduction in residual deviance. This process was repeated until all factors included in the model provided practical benefit to predicting FSM-intention desirability with low

uncertainty. A total of 245 responses were omitted from this analysis due to incomplete data. The statistical significance of each factor in the model was calculated using an analysis of variance (ANOVA) test that compared the full model to the reduced model. A 95%/5% training/testing dataset structure was used, and Nagelkerke's pseudo- R^2 is reported to describe model quality.

RESULTS AND DISCUSSION

Results of practical benefit with low uncertainty are discussed in the following sections, and a summary of these

results is shown in Table 1 for clarity. Comprehensive results are available in the online appendices.

Frequency of undesirable FSM intentions

Responses of 3715 rural latrine owners to the question 'When your pit is getting full, what do you intend to do?' are shown in Table 2, and all contextual factors are shown in Table B1. Four in ten rural latrine owners reported undesirable FSM intentions (41%, Tables 1 and 2). However, few respondents intended to stop using their latrine when their pits fill (2%), and a majority intended to improve their

Table 1 | Summary of important response frequencies, included response values and associations

Response	Included response values	% of responses ^a	Importance of association between response and desirable FSM intentions ^b
Undesirable FSM intentions	Intend to self-empty Undecided Stop using latrine Other	41%	–
Intend to improve latrine within 3 years	Improve shelter Flush-water reservoir Shower New pit Sink Other	54%	0.07 to 0.20*
Adults use latrine frequently	Yes	97%	–
IDPoor	Yes (Type 1 or 2)	55 to 60%	0.05***
Practiced open defecation before installing latrine	Yes	57 to 67%	0.08***
Satisfied with latrine	Very satisfied Somewhat satisfied	86%	0.13***
Recommended owning a latrine	Yes	57–62%	0.05**
Recommended latrine installer	Yes	56–65%	0.09***
Year of data collection	2015, 2016, 2017	51–63%	0.14***
Month of data collection	Jan through Dec	48–73%	0.11***
Rainfall in province	mm rainfall	–	–0.04**
Flooding at household	Yes	–	0.04**
Province that household resides in	Kandal, Prey Veng, Svay Rieng, Banteay Meanchey, Siem Reap, Kampong Thom, Oddar Meanchey	33–76%	0.23***

^aSingle values describe the % of responses across all surveyed households. Ranges describe the % of responses that reported desirable FSM intentions for the possible responses for each factor. See Tables B1 and B2 for details.

^bCramer's v for binary or categorical factors; point-biserial correlation, r_{pb} , for continuous factors. Multiple values indicate the range of importances for factors that have multiple possible responses. See Table B2 for details.

***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$ in association to desirability of FSM intentions.

– Not applicable or no important association found.

Table 2 | Response frequencies of FSM intentions reported by households in rural Cambodia between 2015 and 2017 ($n = 3715$)

Intention when pit fills	# latrine owners responding (% of responses)
Desirable	2181 (59%)
- Pay for professional emptying	1298 (35%)
- Install a new pit	883 (24%)
Undesirable	1534 (41%)
- Self-empty	780 (21%)
- Undecided	612 (16%)
- Stop using latrine	77 (2%)
- Other	65 (2%)

latrine within the next three years (54%), indicating a strong desire to continue using their latrine (Table B1). Relatedly, most respondents reported high satisfaction with their latrine (86%) and high latrine use (97%, Table B1).

The high frequency of undesirable FSM intentions found in this study supports the results of previous research (Still & Foxon 2012; Hussain et al. 2017; PSI 2018), highlighting the imminent problem of achieving safe rural FSM. Moreover, these results may underrepresent the problem. While intending to perform a desirable behavior may not lead to actually performing that desirable behavior (Williams & French 2014), it is unlikely that a latrine owner with *undesirable* FSM intentions will perform a *desirable* FSM behavior due to the additional barriers (e.g., cost) required to perform desirable FSM behaviors (iDE Cambodia 2017). Thus, the frequency of desirable FSM intentions reported in this study likely overpredicts the actual future performance of desirable FSM behaviors by surveyed households.

Awareness of available safe FSM methods likely also plays a strong role in FSM intentions. Many latrine owners did not know what they intended to do when their pits fill (16%, Table 2), implying a lack of awareness of available methods and/or a lack of awareness of the need to manage full pits (Jenkins & Scott 2007; Coffey et al. 2017; Hussain et al. 2017). However, this finding may imply a lack of available, affordable, and/or safe methods when pits fill in the surveyed regions (Jenkins & Scott 2007). Additionally, we found a trend of increasing desirability and a switch from intending to self-empty to intending to install a new pit between 2015 and 2017 (Table B3) that

were likely caused by increasing awareness of installing a new pit as an FSM solution as the technology diffused through the Cambodian sanitation market (iDE Cambodia 2017).

Selected associations

Measured personal, societal, and physical contextual factors were evaluated for association with FSM-intention desirability (Tables 1 and B2). Factors showing associations with low uncertainty and practical benefit are discussed by context category in the following sections.

Personal contextual factors

The poverty level of each household (IDPoor status) showed a significant association with FSM intentions ($p = 0.003$, $v = 0.05$, Tables 1 and B2), as expected from the literature (Hussain et al. 2017). IDPoor households intended to self-empty more than non-IDPoor households (23% vs. 20%), while non-IDPoor households intended to install a new pit more than IDPoor households (25% vs. 21%). The high cost of a new pit or professional emptying compared to self-emptying likely explains these results. IDPoor households have fewer assets; lower incomes and food security; and fewer income-producing members compared to non-IDPoor households (Ministry of Planning Government of Cambodia 2012). Households with lower socio-economic status are also known to be less willing to pay for sanitation infrastructure (Van Minh Nguyen-Viet Thanh & Yang 2013). Thus, IDPoor households likely have a lower willingness to pay for infrastructure improvements, such as a new pit, or infrastructure services, such as professional pit emptying.

Past practice of open defecation showed a significant association with desirable FSM intentions ($p = 0.000$, $v = 0.08$, Tables 1 and B2). Latrine owners that did not previously practice open defecation reported desirable FSM intentions more often (67% vs. 57%).

Desirable FSM intentions also varied significantly with the household's satisfaction with their latrine ($p = 0.000$, $v = 0.13$, Tables 1 and B2). Latrine owners that reported being satisfied or very satisfied with their latrine reported desirable FSM intentions more often (60% vs. 46%) and tended to favor installing a new pit (26% vs. 20%). Latrine

owners that reported being unsatisfied or very unsatisfied about their latrine reported being undecided about their FSM intentions more often (18% vs. 15%). Nearly identical results were found for latrine owners' satisfaction with their latrine's installer ($p = 0.000$; $v = 0.12$, Table B2), implying a lack of distinction between satisfaction with the latrine and latrine installer by the respondent.

The acts of recommending a latrine or a latrine installer to a friend were associated with desirable FSM intentions ($p = 0.01$ and 0.000 , $v = 0.05$ and 0.09 , respectively; Tables 1 and B2). Latrine owners that recommended installing a latrine or recommended their latrine's installer to a friend (recommenders) reported desirable FSM intentions more often (+19% and +21%, respectively) than non-recommenders. Recommenders also reported fewer undecided intentions (-7% and -10%, respectively) and favored installing a new pit more often (+6% and +10%, respectively).

These results all point to the institutionalization of practice when norms and beliefs influence future intentions. While the underlying cause of these connections is unknown, it may be related to making a public commitment to sustainable sanitation (Jenkins & Scott 2007).

Physical contextual factor: survey administration timing

FSM intentions varied with the year of data collection ($p = 0.000$, $v = 0.14$, Tables 1 and B2). The frequency of intending to pay for professional emptying remained relatively constant at ~35% between 2015 and 2017, while the frequency of intending to install a new pit doubled, and the frequency of intending to self-empty halved (Table B3). Indecision was common among latrine owners (11% to 19%), while intending to stop using a latrine or having other intentions remained low (Table B3).

FSM intentions varied by month during the final year of surveying ($p = 0.000$, $v = 0.11$, Figure 1, Tables 1 and B2). This timeframe was selected due to the large number of surveys administered, continuity of surveying, and distribution across provinces. Desirable FSM intentions averaged 62% with a standard deviation of 7%, being highest in April (73%) and September (72%), and lowest in November (50%). Intending to pay for professional emptying peaked in April (49%) and was most frequently reported in all months except September and November. Intending to self-empty varied between 14% and 22% throughout most of the year but peaked in November (30%). Having other

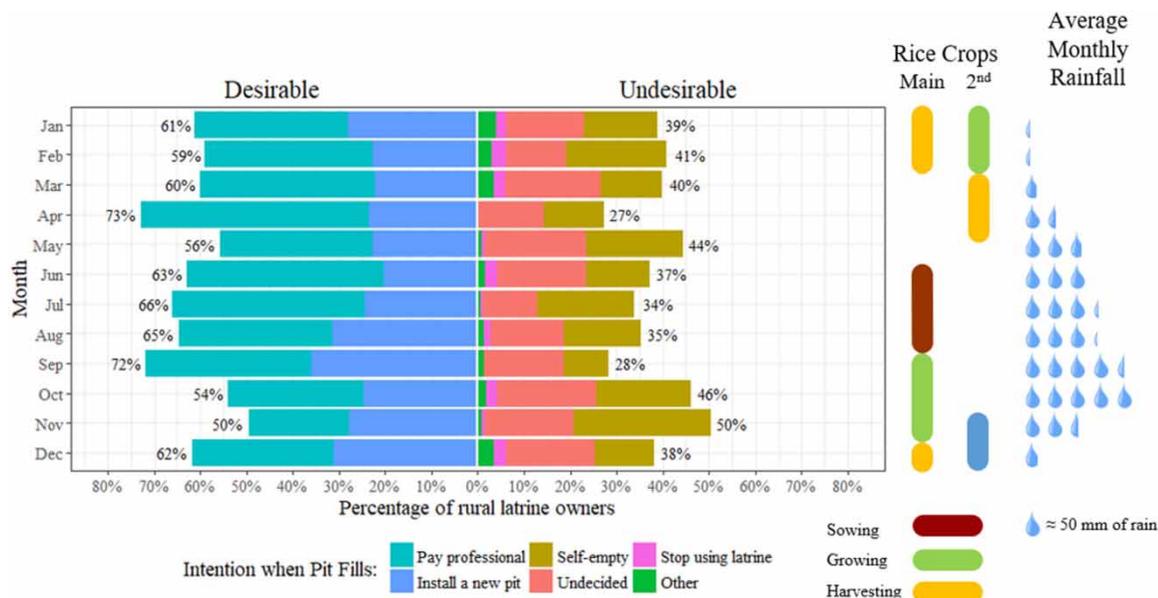


Figure 1 | Percentages of rural Cambodian latrine owners reporting FSM intentions aggregated by month and desirability between October 2016 and September 2017 with the Cambodian rice crop calendar and average monthly rainfall ($n = 2524$, $p = 0.000$, $v = 0.11$) (Food and Agriculture Organization of the United Nations (2018); Thoeun (2015); United States Department of Agriculture, Foreign Agricultural Service (2010)).

intentions and stopping use of a latrine remained infrequent across all months.

These monthly variations show associations with seasonal agricultural processes. Rice cultivation comprises much of the economies in the surveyed provinces (Food and Agriculture Organization of the United Nations 2014). According to the rice crop calendar, farmers likely earn little income and experience high work demands during November, when they are growing and perhaps sowing rice, which may explain the low frequency of desirable FSM intentions. Harvest brings income and food security, which may explain the increase in desirable FSM intentions, particularly paying for professional emptying, in April. This seasonality of FSM intentions mirrors findings that seasonal fluctuations in income affect households' abilities to pay for FSM services in the pre-harvest wet season due to agricultural debts (Kong & Bartell 2018). Given this seasonality, there also may be an opportunity to develop alternative payment mechanisms that consider seasonal intentions and timing of ability to pay to promote more desirable FSM solutions in the rural context.

Physical contextual factor: rainfall and flooding

Rainfall rapidly changes sludge levels in pits (Strande & Brdjanovic 2014). However, average monthly rainfall very weakly affected FSM-intention desirability across all provinces ($p = 0.03$, $r_{pb} = -0.04$, Figure 1, Tables 1 and B2). Rainfall in Prey Veng showed a weak negative association with desirable FSM intentions ($p = 0.001$, $r_{pb} = -0.12$), while rainfall in Kampong Thom showed a weak positive association ($p = 0.05$, $r_{pb} = 0.10$). Additional rainfall in Kampong Thom may benefit its small-scale aquaculture economy and explain this variation in FSM intentions (Hori et al. 2006). No significant associations were found between desirable FSM intentions and rainfall in the other five provinces ($p > 0.18$).

Heavy rainfall and other events can lead to flooding, rendering most in-ground latrine designs dysfunctional by filling pits and preventing flushing; fecal sludge may even spill into the environment uncontained (Strande & Brdjanovic 2014). Despite flooding being common in the surveyed provinces (iDE Cambodia 2017), flooding causing

latrine dysfunction had only a very weak effect on the desirability of FSM intentions ($p = 0.02$, $r_{pb} = 0.04$, Tables 1 and B2).

These results were unexpected because rainfall is known to strongly affect pit sludge levels (Strande & Brdjanovic 2014). However, results showed that unless a pit overflows, which was reported rarely (1%, Table B1), latrine owners do not change their FSM intentions based on their pit's sludge levels. Thus, it is likely that latrine owners are not typically aware of their pits' sludge levels, which presents an opportunity for future work that examines whether awareness of pit sludge levels affects FSM intentions. Additionally, flooding may not be seen as a 'challenge' because 'flooding out' is commonly used to empty pits (iDE Cambodia 2017). Thus, additional studies are needed to describe the complex effects that flooding has on FSM intentions in rural Cambodia.

Physical contextual factor: province and district

Strong variations in FSM intentions were found across provinces ($p = 0.000$, $v = 0.23$, Figure 2, Tables 1 and B2). The frequency of desirable FSM intentions varied from 76% in Banteay Meanchey to 33% in Siem Reap. Intending to pay for professional emptying was very common in Banteay Meanchey (72%), while intending to install a new pit was more frequently reported in Svay Rieng (44%). Latrine owners in Siem Reap also reported being undecided (32%) or intending to self-empty (34%) more than those in other provinces. These variations in FSM intentions across provinces could not be explained by available data, including a metric of provincial-level poverty that identifies deprivations in health, education and standard of living using household surveys (the Multidimensional Poverty Index of the Oxford Poverty and Human Development Initiative (OPHI) and the United Nations Development Programme). These variations in FSM intentions across provinces are discussed in detail in Appendix C.

Predicting FSM intentions

A binomial logistic regression model was used to examine the relative strengths of the associations between contextual factors and FSM intentions described above, and identify

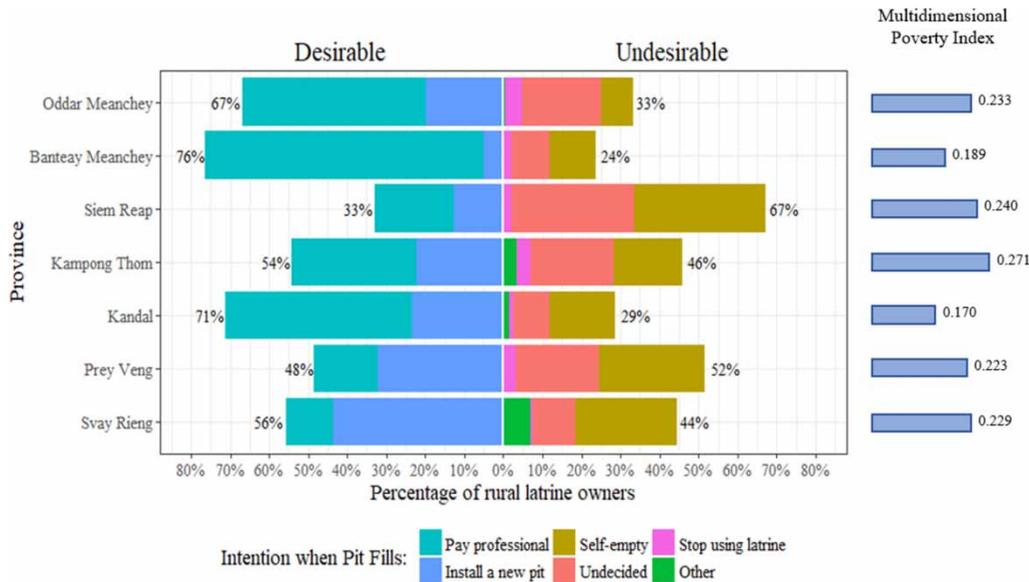


Figure 2 | Percentages of rural Cambodian latrine owners reporting FSM intentions aggregated by province and desirability between 2015 and 2017 ($n = 3715$, $p = 0.000$, $v = 0.23$) with the multidimensional poverty index of each province (higher indicates more poverty). Provinces are arranged by geographical proximity, starting in the north of Cambodia (Oxford Poverty and Human Development Initiative 2013).

any confounding in the above results. The final model used nine contextual factors as inputs and predicts FSM-intention desirability via Equation (1):

$$\text{logit} [P(\text{desirable FSM intention})] = \alpha + \sum_{i=1}^9 \beta_i x_i \quad (1)$$

where $\text{logit} [\dots]$ describes the log of the odds of reporting a desirable FSM intention, $\log \left[\frac{P(\text{desirable FSM intention})}{1 - P(\text{desirable FSM intention})} \right]$; α is the intercept; and β_i are the slope coefficients associated with the factors x_i , which are the province in which the latrine owner lives (*Province*), the satisfaction of the latrine owner with their latrine (*Satisfaction*), the month the latrine owner was surveyed (*Month*), whether the latrine owner had recommended their latrine’s installer to a friend (*RecommendedInstaller*), the year the latrine owner was surveyed (*Year*), the satisfaction of the latrine owner with their latrine’s installer (*SatisfactionInstaller*), whether the latrine owner practiced open defecation before constructing a latrine (*PastOpenDefecation*), whether the latrine owner reported flooding as a problem with their latrine (*Flooding*), and the IDPoor status of the latrine owner (*IDPoor*).

The resulting equation is:

$$\begin{aligned} &\text{logit} [P(\text{desirable FSM intention})] \\ &= \alpha + \beta_1 \times \text{Province} + \beta_2 \times \text{Satisfaction} + \beta_3 \\ &\quad \times \text{Month} + 0.43 \times \text{RecommendedInstaller} + \beta_5 \times \text{Year} \\ &\quad + \beta_6 \times \text{SatisfactionInstaller} - 0.28 \\ &\quad \times \text{PastOpenDefecation} - 1.05 \times \text{Flooding} - 0.22 \times \text{IDPoor} \end{aligned} \quad (2)$$

where $\beta_1 = [-2.03, -0.47]$, $\beta_2 = [-0.53, 2.06]$, $\beta_3 = [-0.13, 0.66]$, $\beta_5 = [0.37, 0.82]$, and $\beta_6 = [0.10, 2.48]$, where ‘[_, _]’ indicates the range of estimates for the various responses for each factor (see Table B5 for confidence intervals and other details).

Characteristics of each factor in the model are shown in Table B4; factors are arranged by decreasing deviance, which describes the statistical importance of each factor. Estimates, standard errors, confidence intervals, z-values and significances of the coefficients in the binomial logistic regression model are shown in Table B5.

All of the results described in the above sections are reproduced in the model. Additionally, the model shows that *Satisfaction* has a high deviance, and its estimates show that any satisfaction score other than 1 (very unsatisfied) is a good predictor of desirable FSM intentions.

Conversely, *SatisfactionInstaller* is a good predictor of desirability only with a score of 5 and has a markedly lower deviance. *RecommendedInstaller* is nearly as important as *Month*, and *PastOpenDefecation*, *Flooding*, and *IDPoor* are all good predictors of *undesirable* FSM intentions.

The model predicts the FSM-intention desirability of rural Cambodian latrine owners with an accuracy of 67% (Nagelkerke's pseudo- $R^2 = 0.27$), while the reduced model predicts with an accuracy of 59% (i.e., the percentage of latrine owners reporting desirable FSM intentions).

The associations found between FSM intentions and contextual factors were relatively weak individually, mirroring other studies of intention and context (Gamma et al. 2017). However, considering these weak associations together via regression yielded marked improvements and new results in predicting intention. Despite this, model accuracy remained low, highlighting the disconnect between context and intention that is described in theories of decision-making in the form of behavioral determinants (Darnton 2008). Thus, although model accuracy and quality could be improved by considering additional relevant contextual factors that are currently not identified, contextual factors that are commonly measured by development practitioners and other agencies are unlikely to produce useful predictions of intention without also measuring behavioral determinants.

Recommendations for development practitioners

Understanding how contextual factors affect FSM intentions provides practical benefit to the development of social marketing, behavior change campaigns, and product designs related to FSM. For example, the currently accepted best practice for safe FSM in rural Cambodia is installing an alternating dual-pit latrine (iDE Cambodia 2018). Because a household will require desirable FSM intentions to install a new pit, we recommend using behavior change campaigns in addition to traditional sales techniques in provinces where intentions to install a new pit are low (e.g., Siem Reap, Kampong Thom) and particularly where potential for market expansion is high (e.g., Banteay Meanchey, Kandal). This method should increase the number of alternating dual-pit latrines in rural Cambodia more efficiently than if behavior change campaigns are not used to increase

the frequency of desirable FSM intentions. Conversely, only traditional sales techniques are recommended in provinces like Svay Rieng and Prey Veng, where intentions to install a new pit are higher.

Regarding timing, we recommend increasing marketing and behavior change communication in the months preceding and including April when farmers are most financially and food secure. At other times of the year, particularly in November when FSM intentions are least desirable, alternative payment plans should be advertised more strongly to encourage selecting desirable FSM solutions.

Regarding sanitation product design, affordable technologies should be improved and made aspirational to both IDPoor and non-IDPoor families, particularly those that are already satisfied with their latrines. Specifically, latrine systems that work effectively in environments that experiencing flooding should be of high priority.

Limitations and recommendations for future work

Analyzing the desirability of FSM intentions instead of specific FSM intentions improved generalizability but likely obscured important details. Social desirability bias may have also affected responses due to the sensitive nature of the topics discussed in the survey, and survey length (67 questions) may have produced survey fatigue, biasing responses regarding FSM intentions (question number 61). Courtesy bias, which occurs when a household is not wholly honest in their response to a question to avoid offending the person or organization asking the question, may have affected satisfaction responses because iDE employees also facilitated latrine sales; however, this bias is likely minimal because the topic addressed in the survey – the latrine installers – are not iDE employees.

Ideally, all components of the decision-making process should be characterized in detail to understand how intentions are formed and explain any differences between intentions and behaviors that may occur. This requires a targeted study design and enormous person-hour investment for study development and data collection and analysis. We recommend that future work conduct a comprehensive study that characterizes each component of the decision-making process, including behavioral determinants and control-related topics, of rural Cambodian latrine owners when pits fill.

Future work should also randomize question order to reduce bias and survey households that purchased latrines outside of iDE's sales network to improve generalizability. Future studies should continue to employ local research assistants of the same gender as respondents, and respondents should be encouraged to be wholly honest in their responses. Lastly, while the rural areas of the provinces surveyed are like many other rural areas in other Cambodian provinces, additional research should be performed to ensure accurate generalizability of this study's results to other Cambodian provinces.

CONCLUSIONS

Latrine owners living in rural Cambodia were surveyed to determine their intentions when their latrine pits fill with fecal sludge. Four in ten households reported undesirable FSM intentions, highlighting an impending risk to public and environmental health due to unsafe FSM. Many associations were found between FSM intentions and contextual factors, including the province in which latrine owners lived, the year and month a latrine owner was surveyed, the household's satisfaction with its latrine and its installer, and the household's IDPoor status. However, even when considering all important contextual factors, accurately predicting desirable FSM intentions proved difficult, with the model yielding an accuracy of 67% and low quality.

With recent rapid improvements in latrine access after decades of effort and enormous monetary investment, it is critical that the associated improvements in public health continue to push rural communities globally towards achieving the goals of SDG6 (UN 2018). This will require achieving safe FSM in rural communities globally and will rely on a thorough understanding of how households make decisions when their latrine pits fill.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this paper is available online at <https://dx.doi.org/10.2166/washdev.2020.103>.

REFERENCES

- Asia Foundation 2007 *The Provincial Business Environment Scorecard in Cambodia, A Measure of Economic Governance and Regulatory Policy*. Retrieved from <https://asiafoundation.org/resources/pdfs/CBPBESchcheng.pdf>.
- Asian Development Bank 2014 *Cambodia Country Poverty Analysis*. Retrieved from <https://www.adb.org/sites/default/files/institutional-document/151706/cambodia-country-poverty-analysis-2014.pdf>.
- Coffey, D., Spears, D. & Vyas, S. 2017 *Switching to Sanitation, Understanding Latrine Adoption in A Representative Panel of Rural Indian Households*.
- Darnton, A. 2008 An overview of behaviour change models and their uses. *GSR Behaviour Change Knowledge Review*.
- Fishbein, M. & Ajzen, I. 2011 *Predicting and Changing Behavior: The Reasoned Action Approach*. Psychology Press, New York, USA.
- Food and Agriculture Organization of the United Nations 2014 *Country Fact Sheet on Food and Agriculture Policy Trends, Cambodia*. Retrieved from www.fao.org/3/a-i3761e.pdf.
- Food and Agriculture Organization of the United Nations 2018 *Country Analysis, Cambodia*. Retrieved from www.fao.org/giews/countrybrief/country.jsp?code=KHM.
- Gamma, A. E., Slekiene, J., von Medeazza, G., Asplund, F., Cardoso, P. & Mosler, H.-J. 2017 Contextual and psychosocial factors predicting Ebola prevention behaviours using the RANAS approach to behaviour change in Guinea-Bissau. *BMC Public Health* 17 (1), 446. <https://doi.org/10.1186/s12889-017-4360-2>.
- Google Earth Pro 2016 *Cambodia*. 48P, 498254E, 1384607N, WGS 84.
- Hori, M., Ishikawa, S., Heng, P., Thay, S., Ly, V., Nao, T. & Kurokura, H. 2006 Role of small-scale fishing in Kompong Thom Province, Cambodia. *Fisheries Science* 72 (4), 846–854. <https://doi.org/10.1111/j.1444-2906.2006.01226.x>.
- Hussain, F., Clasen, T., Akter, S., Bawel, V., Luby, S. P., Leontsini, E. & Winch, P. J. 2017 Advantages and limitations for users of double pit pour-flush latrines: a qualitative study in rural Bangladesh. *BMC Public Health* 17, 515. <https://doi.org/10.1186/s12889-017-4412-7>.
- iDE Cambodia 2017 *Fecal Sludge Management Research Compendium*.
- iDE Cambodia 2018 *FSM Commercialization Study*.
- Jenkins, M. W. & Scott, B. 2007 Behavioral indicators of household decision-making and demand for sanitation and potential gains from social marketing in Ghana. *Social Science & Medicine* (1982) 64 (12), 2427–2442. <https://doi.org/10.1016/j.socscimed.2007.03.010>.
- Jenkins, M. W., Cumming, O. & Cairncross, S. 2015 Pit latrine emptying behavior and demand for sanitation services in Dar es Salaam, Tanzania. *International Journal of Environmental Research and Public Health* 12 (3), 2588–2611. <https://doi.org/10.3390/ijerph120302588>.

- Kong, M. & Bartell, J. 2018 *Behavioral Drivers of Fecal Sludge Management in Rural Cambodia: A Qualitative Study (Technical Report)*. WaterSHED.
- Ministry of Planning, Government of Cambodia 2012 *IDPoor Atlas: Results From Data Collection Rounds 4 (2010) and 5 (2011), Identification of Poor Households Programme*. Retrieved from www.idpoor.gov.kh/Data/En/Reference/IDPoor_ATLAS_Round_4_5_Eng-FINAL.pdf.
- National Institute of Statistics, Ministry of Planning, Government of Cambodia 2012 *Economic Census of Cambodia, National Report*. Retrieved from www.nis.gov.kh/nis/EC2011/EC2011_Final_Results_Revised.pdf.
- OpenDevelopment Cambodia 2018 *Water Bodies in Cambodia*. Retrieved from <https://opendevdevelopmentcambodia.net/dataset/?id=water-bodies-in-cambodia>.
- Oxford Poverty and Human Development Initiative 2013 *Cambodia Country Briefing, Multidimensional Poverty Index Data Bank*. Retrieved from www.ophi.org.uk/multidimensional-poverty-index/mpi-country-briefings/.
- PSI 2018 *Household Pit Emptying and Sludge Reuse Practices in Rural Cambodia*. Retrieved from https://drive.google.com/open?id=1uDYogk0X7-yzUoRtWP5dYNmTIsCl9UX_.
- Sample, E. D., Evans, B. E., Camargo-Valero, M. A., Wright, N. G. & Leton, T. G. 2016 *Understanding the drivers of sanitation behaviour in riverine communities of Niger Delta, Nigeria: the case of Odi and Kaiama communities*. *Journal of Water, Sanitation and Hygiene for Development* **6** (3), 491–499. <https://doi.org/10.2166/washdev.2016.050>.
- SNV 2019 *SSH4A III Beyond ODF, FSM Research*. Retrieved from <https://drive.google.com/open?id=1B2ihcp0Ip7ZHGz8bpHY8J1d-NTHWyraP>.
- Still, D. & Foxon, K. 2012 *Tackling the Challenges of Full pit Latrines*. Water Research Commission, South Africa.
- Strande, L. 2014 The Global Situation. In: *Fecal Sludge Management: Systems Approach for Implementation and Management* (L. Strande, M. Ronteltap & D. Brdjanovic eds). IWA Publishing, London, UK, pp. 1–14.
- Strande, L. & Brdjanovic, D. 2014 *Faecal Sludge Management: Systems Approach for Implementation and Operation*. Retrieved from www.eawag.ch/en/department/sandec/publications/faecal-sludge-management-fsm-book/.
- Thoeun, H. C. 2015 *Observed and projected changes in temperature and rainfall in Cambodia*. *Weather and Climate Extremes* **7**, 61–71. <https://doi.org/10.1016/j.wace.2015.02.001>.
- UN 2018 *Status and Trends of Progress of SDG 6, Highlights*.
- United States Department of Agriculture, Foreign Agricultural Service 2010 *Commodity Intelligence Report, Cambodia*. Retrieved from <https://ipad.fas.usda.gov/highlights/2010/01/cambodia/>.
- Van Minh, H., Nguyen-Viet, H., Thanh, N. H. & Yang, J.-C. 2013 *Assessing willingness to pay for improved sanitation in rural Vietnam*. *Environmental Health and Preventive Medicine* **18** (4), 275–284. <https://doi.org/10.1007/s12199-012-0317-3>.
- Wasserstein, R. L., Schirm, A. L. & Lazar, N. A. 2019 *Moving to a world beyond 'p < 0.05.'* *The American Statistician* **73** (sup1), 1–19. <https://doi.org/10.1080/00031305.2019.1583913>.
- Williams, S. L. & French, D. P. 2014 *Theory of planned behaviour variables and objective walking behaviour do not show seasonal variation in a randomised controlled trial*. *BMC Public Health* **14** (1), 120. <https://doi.org/10.1186/1471-2458-14-120>.

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